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RAW WATER SUPPLY SCHEME IN MOROTAI ISLAND

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ABSTRACT Morotai Island was designated as one of the National Tourism Strategic Area. It will certainly increase the raw water demand on Morotai Island. This island is known as a dry area that difficult to get water, so it is necessary to prepare the raw water supply scheme for water demand. Several methods used in this research include water demand calculation for domestic, industry, irrigation, livestock, and tourism; rainfall-runoff simulation using WFLOW model; and estimation of groundwater availability using the baseflow recession method. Surface water balance shows that the water availability of each sub-districts is not able to fulfil the all water demand. To overcome this problem, raw water supply scheme has been prepared, e.g. surface water utilisation in North Morotai by constructing free intake; groundwater utilisation in most area especially coastal area by constructing dug wells and drilled wells; spring water utilisation in Morotai Jaya, East Morotai, and South Morotai by constructing spring water collection system (broncaptering). The water supply scheme suggests the appropriate infrastructure to support the raw water supply for local communities, as well as for the development of Morotai Island to be the new primary tourism destination in Indonesia.

KEYWORDS raw water, tourism, water deficit, water resources infrastructure, Morotai

1 INTRODUCTION

Indonesia is an archipelagic country that consists of both big and small islands with abundant natural resources. One of the small islands that potential to be developed is Morotai Island. Because of its natural beauty, the island located in the Northern part of the Maluku Islands, known as the hidden paradise of East Indonesia. Based on the Republic of Indonesia Government Regulation No. 50 of 2011 concerning Master Plan of National Tourism Development for 2010 – 2025, Morotai Island was designated as one of the National Tourism Strategic Area (Republic Indonesia, 2011), so that the development of this region is prioritized for the tourism sector. Tourism sites in Morotai Island include the underwater tour, small islands, cave, World War II museum, waterfall, and so on.

The development of an area will increase raw water demand and also the infrastructure for raw water supply. Morotai Island is known as a dry area that difficult to get water, so it is necessary to prepare the raw water supply scheme for total water demand. According to Soenarto et al. (2010), clean water sources in small islands are very limited, due to their position which is isolated by the surrounding sea. Water demand for tourism sector can generate sustainability problems of the water resources, especially in those regions where water is scarce, as occurs at most coastal and small island destinations (Tortella & Tirado, 2011; Ecologic, 2007; Essex et al., 2004; Gikas & Tchobanoglous, 2009; Gössling, 2001; Kent et al., 2002; Pigram, 2001; UNEP, 2009). The study aims to obtain a raw water supply scheme from various water sources available in Morotai Island to fulfil the all water demand, especially for tourism sector development.

Morotai Island is included in North Maluku Province which is geographically located at the coordinate of $2^0\ 00'$ – $2^040'$ N and $128^015'$ – $129^008'$ E. The area of Morotai Island is 4301.53 km^2 consisting of 2314.9 km^2 land area and 1970.93 km^2 sea area. Based on the type of island which is classified by Soenarto et al. (2010), Morotai island can be categorised as a small island since the area of the island is $\leq$ 5.000 km^2. The Pacific Ocean restricts this island in the Northern part, the Halmahera Sea in the Western and Eastern regions, and Morotai Strait in the Southern part (BPS, 2017).

The rainfall pattern in Morotai Island is unique, can be categorised as a monsoon type which is influenced by the local factor (Aldrian & Susanto, 2003; Visa & Harjana, 2015). It can be seen on two peaks of the rainy season, namely

December-January-February and May-June. This island is included in Halmahera Utara River Basin. River flows have a dendritic pattern which indicates that the island generally has a sloping topography. The rivers flow to the West and East with widths ranging from 4 – 80 m. In terms of groundwater condition, Morotai island has one groundwater basin, namely Daruba – Bere-bere with an area of 486 km^2 or about 21% from the total area of Morotai Island. The groundwater basin is laying on the coastal area of Morotai Island especially in East dan South, with lithology in the form of gravel, sand, clay, and boulder. This area is categorised as aquifers with moderate productivity and locally productivity. This information is used as one consideration in determining the raw water supply schemeMETHODS

2 METHODOLOGY

Data used in this study include statistical data for water demand calculation; discharge measurement and water level data which is monitored by river gauging installation at several points in the river; groundwater sources data from field survey such as springs, dug wells, and drilled wells; and the supporting data and maps as well.

2.1 Water Demand Calculation

The water demand calculation is referred to SNI 6728.1-2015 concerning the preparation of Water Resources Balance which includes water demand calculation of domestic, urban, industry, irrigation, and livestock. Tourism water demand follows the criteria set by Ditjen Cipta Karya (1996). Domestic water demand is determined based on the city types, as presented in Table 1. Urban water demand (non-domestic) is assumed to be between 15% to 30% of domestic water demand. The bigger and denser the population, the higher the demand for non-domestic water. Industrial water demand can be calculated based on the number of employees, the area of the industry, and types of industry.

Table 1 Domestic water demand based on categories of city

No	Categories of City	Total Population (capita)	Water demand (L/capita/day)
1	Capital of district/ village	3,000 – 20,000	60 – 90
2	Small city	20,000 – 100,000	90 – 110
3	Medium city	100,000 – 500.000	100 – 125
4	Big city	500,000 – 1,000,000	120 – 150
5	Metropolitan	>1,000,000	150 – 200

(Source: BSN, 2015)

The water demand for livestock is determined based on the number and types of livestock using the following equation.

$$Q_E = \left(q_{(1)}\, x\, P_{(1)} + q_{(2)}\, x\, P_{(2)} + q_{(3)}\, x\, P_{(3)} \right) \qquad (1)$$

In Equation 1, Q_E is water demand for livestock (L/day), $q_{(1)}$ is the water demand for a cow, buffalo, and horse (L/capita/day), $q_{(2)}$ is the water demand for goat and sheep (L/capita/day), $q_{(3)}$ is the water demand for poultry (L/capita/day), $P_{(1)}$ is the number of cows, buffalo, and horse (capita), $P_{(2)}$ is the number of goat and sheep (capita), and $P_{(3)}$ is the number of poultry (capita). The water demand for each type of livestock is presented in Table 2.

Table 2 Water demand for livestock

No	Types of Livestock	Water demand (Liter/capita/day)
1	Cow/buffalo/horse	40
2	Goat/sheep	5
3	Pig	6
4	Poultry	0.6

(Source: BSN, 2015)

Calculation of irrigation water demand requires supporting data include planting area, planting schedule, evapotranspiration, effective rainfall, soil type, and irrigation channel efficiency. Water demand for irrigation is calculated based on the area of the field with the water demands per unit area as follows.

$$IG = \frac{(E_{tc} + IR + RW + P - ER)}{IE} \, x \, A \qquad (2)$$

Where IG is the irrigation water demand (m^3), E_{tc} is the consumptive water demand (mm/day), IR is the water demand for land preparation (mm/day), RW is the water demand to replace water layer (mm/day), P is the percolation (mm/day), ER is the effective rainfall (mm/day), IE is the efficiency of irrigation, and *A* is the area of irrigation (m^2)

Water demand for hotels and tourism use criteria, as presented in Table 3.

Table 3 Calculation criteria of hotels and tourism water demand

No	Description	Unit	Value
1	Hotel	L/bed/day	150
2	Tourism area	L/s/ha	0.1 – 0.3

(Source: Ditjen Cipta Karya, 1996)

2.2 Rainfall-Runoff Simulation

In determining the reliability of river discharge at a particular location, required long and continuous discharge data, while the discharge data availability in Morotai island is very limited. There is only one discharge gauge located in South Morotai, namely Aha station which only has data for one year. In this study, surface water availability is obtained from rainfall-runoff simulation using WFLOW model. WFLOW is a fully distributed hydrological model that can simulate the processes in the hydrological cycle, starting from rainfall until getting the flow in the river. WFLOW consists of 3 sub-module as follows: interception module calculated by Gash model schematisation, soil module (TOPOG_SBM model) include lateral groundwater flow and kinematic wave routing module. Input data required daily rainfall data from TRMM satellite and evapotranspiration data from CGIAR from 2002 to 2017. Supported by static data in the form of topography, land use, soil type, and so on.

2.3 Groundwater Recharge Estimation

In this study, groundwater availability is estimated through the calculation of recharge capacity by applying the baseflow recession method. Baseflow is water flows that reach the groundwater level and flows in the aquifer until it fills out the river body (Fetter, 2001). The baseflow recession method is applied as an approach to calculate the amount of recharge capacity that is represented as baseflow that comes out to surface water after the end of the rainy season. The term recession refers to the decrease of output (discharge) naturally due to the absence of input (recharge) that follows an exponential pattern (Domenico & Schwartz, 1990). In this calculation, it is assumed that the groundwater flows to the surface, both directly and through spring, so that baseflow value can be determined as groundwater recharge. The calculation of baseflow recession is performed on hydrograph at a single location as a function of time. The formulation used in the calculation is as follows.

$$K = \left(\frac{Q_t}{Q_0} \right)^{\frac{1}{t}} \qquad (3)$$

$$k = -\ln K \qquad (4)$$

Where Q_0 is the initial discharge value (m^3/s),

Q_t : discharge value at time “t” (m^3/s)
k : baseflow recession value (day^{-1})
t : time (day)

Baseflow recession value can be used to estimate groundwater storage value and recharge capacity with the following equation.

$$V_t = \frac{Q_t}{k} \qquad (5) \qquad R = \frac{V_t}{L} \qquad (6)$$

where:

V_t = groundwater storage (m^3)
L = catchment area (m^2)
Groundwater recharge value is obtained by dividing groundwater storage value by the watershed area.

3 RESULTS AND DISCUSSION

3.1 Water Demand

The results of the water demand calculation indicate that the total domestic water demand in Morotai Island is 128.28 L/s. The highest domestic water demand is in South Morotai, i.e. 47 L/s since there is an urban centre located in that region named Daruba City. Industrial water demand on Morotai island is only 0.67 L/s. However, based on the spatial plan (RTRW) of Morotai District 2012 – 2032, the marine energy and copra industry will be developed in Morotai Jaya, and the water consumption is estimated around 781 L/s.

Irrigation water demand is calculated in 6 irrigation areas (DI), namely DI Aha and DI Daeo in South Morotai; DI Tiley in South West Morotai; DI Sambiki, DI Sangowo, and DI Wewemo in East Morotai with total irrigation area of 632 Ha. The average irrigation water demand in South Morotai is 1042.6 L/s, South West Morotai is 502.1 L/s, and East Morotai is 446.8 L/s. Livestock in Morotai Island includes poultry, goat, cow, duck, pig, and buffalo with population-level around 10 – 13%. The highest livestock water demand is in South Morotai, i.e. 0.002 L/s, while in other subdistricts is around 0.001 L/s. The result of tourism water demand calculation, the highest is in South Morotai, i.e. 80.4 L/s, while in other regions namely South West Morotai and North Morotai are 57.81 L/s and 2.96 L/s respectively. Currently, water supply for tourism utilises water from rivers, springs, and dug wells. The highest water demand is in the South Morotai due to the high development in this area. The total water demand for each sub-district is presented in Table 4. The highest water demand is in South Morotai, i.e. 812.9 L/s followed by Morotai Jaya 795 L/s, South West Morotai 417.3 L/s, East Morotai 308.4 L/s, and North Morotai 28.2 L/s.

Table 4 Total water demand in Morotai Island

No	Sub-district	Total Water Demand (L/s)
1	South Morotai	812.9
2	East Morotai	308.4
3	South West Morotai	417.3
4	North Morotai	28.2
5	Morotai Jaya	795.0

3.2 Water Availability

Analysis of water availability begins with water resources identification through field surveys. Based on the geological survey, Morotai Island is dominated by limestone and other types of rocks such as lava, breccia, sand, and silt. Information about lithology can be used as an initial description related to groundwater potential in this region. Water sources identified based on field surveys include river, spring, dug wells and drilled wells. It is believed that there are still other water sources that have not yet been identified. Springs that emerge are generally due to rock fractures of limestone formation or underground river that emerge to the surface.

Besides in the main island, field survey is also conducted in the surrounding small islands. From 33 small islands located in Morotai Island District, 14 islands have been visited (Table 5). The island that is the second-largest area after the main island is Rao Island with an area of less than 1 km^2. Those islands are mostly inhabited by tourism service officials. Some islands that functioned as a tourism destination are Zumzum, Dodola Besar, Dodola Kecil, Galo – Galo Kecil, Kokoya, Dowongidare, and Matita. Rao Island is only functioned as a residence, while other islands are not only for residences but also for fishing and tourism destination. The result of small islands identification can be seen in Figure 1.

Table 5. Raw water source identification in small islands surrounding Morotai.

No	Name of Island	Area (km^2)	Function	Water Sources
1	Tabailenge	0.10	Fishing and tourism	Not available
2	Rao	60.86	Residence	River, spring, and dug wells

3	Saminyamau	0.39	Residence and tourism	Dug wells and from spring in Rao
4	Ngele - ngele Besar	1.42	Residence and tourism	Dug wells
5	Ngele - ngele Kecil	0.12	Residence and tourism	Dug wells
6	Zumxum	0.73	Tourism	Dug wells
7	Kolorai	0.19	Residence and tourism	Dug wells
8	Dodola Besar	0.71	Tourism	Dug wells
9	Dodola Kecil	0.07	Tourism	Not available
10	Galo-galo Besar	0.32	Residence and tourism	Dug wells
11	Galo-galo Kecil	0.12	Tourism	Not available
12	Kokoya	0.12	Tourism	Dug wells
13	Dowongidare	0.005	Tourism	Not available
14	Matita	0.43	Tourism	Not available

In terms of water sources that utilised, almost all islands have dug wells to utilise groundwater for the water demand, including Rao, Saminyamau, Ngele–ngele Besar, Ngele–ngele Kecil, Zumzum, Kolorai, Dodola Besar, Galo–galo Besar, and Kokoya with water depth ranging from 1 – 4.5 meter (Table 5). In terms of quality, the value of Electrical Conductivity (EC) and Total Dissolved Solids (TDS) have not shown the effect of seawater intrusion. Therefore, more detail studies are needed regarding this matter. In addition, the other water sources are also found in Rao Island in the form of springs and rivers such as Galopu river, Buras river, Dolam river, and Cebubu spring. Buras river discharge is the potential to be developed with measured discharge is 26 L/s.

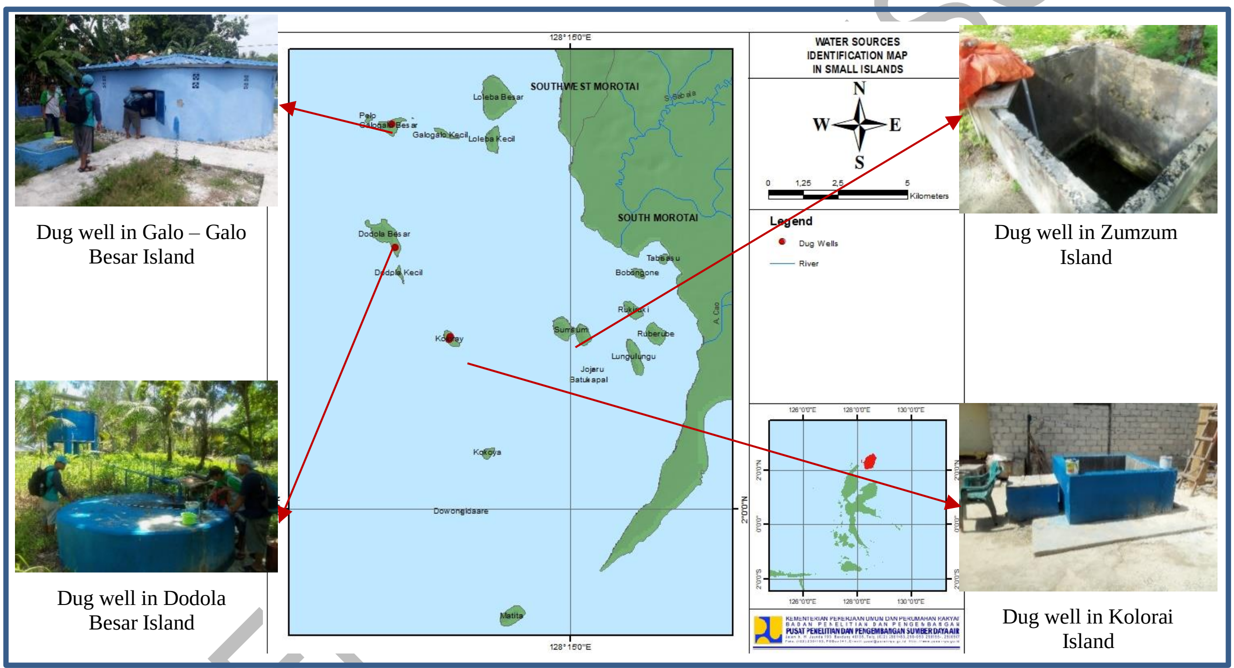

Figure 1 Water sources identification map in small islands

The results of the field survey and water source identification are not enough to describe a whole water availability potential. Therefore, the rainfall-runoff simulation was conducted to obtain dependable flow in each sub-catchment. The rainfall-runoff model used in this study is a distributed hydrological model by WFLOW, where the calculation process in the model is carried out in each grid. The hydrological model is used to simplify the complex real-world in models. WFLOW model for Morotai is built with a tool called WFLOW-model builder with local and global data input (if there are no data local available). Since the area of Morotai Island is quite small, more detail maps are needed. Local maps used in this model include river network, land use, and soil type maps, with the grid size of the model is 100 m.

After the model successfully built, the next step is to prepare the dynamic data input include rainfall data from TRMM satellite with a length of 16 years and evapotranspiration from CGIAR. Discharge generated from the model then processed to obtain the dependable flow in each catchment. The result shows that the surface water sources in Morotai Island are potential to be developed, even more, if there is adequate infrastructure for the community in accessing water. It certainly supported by the rainfall pattern with has two peaks of the rainy season. There are some potential catchments, i.e. Cao, Sabatai Tua, Sakita, Tatamo, and Yao with Q_{90} more than 5 m^3/s.

To anticipate the deficit condition of surface water, this study is estimated the groundwater potential represented by recharge capacity in each catchment by applying the baseflow recession method. The recharge capacity of each catchment in Morotai Island is in the range of 13.57 – 721 mm/year. The percentage of recharge are ranging from 1% - 40% of the amount of rainfall. Some catchments with recharge capacity more than 300 mm/year are Cio, Tutuhu, Sabatai Tua, Sangowo Kecil, Sangowo, and Lusuo.

3.3 Water Balance

Morotai consists of 5 subdistricts, and each of them has a capital city, where regional development occurs. The balance of water availability and water demand for each water district can be seen in Figure 2. Surface water balance shows that the water availability Q90 of each sub-districts can not fulfil all water demand. From 5 sub-districts only North Morotai is having surplus throughout the year. South Morotai is a deficit in April, East Morotai is a deficit in April and November, South West Morotai and Morotai Jaya are a deficit for a whole year. Based on that result, it is necessary to utilize the other raw water sources to meet the water demand in Morotai Island.

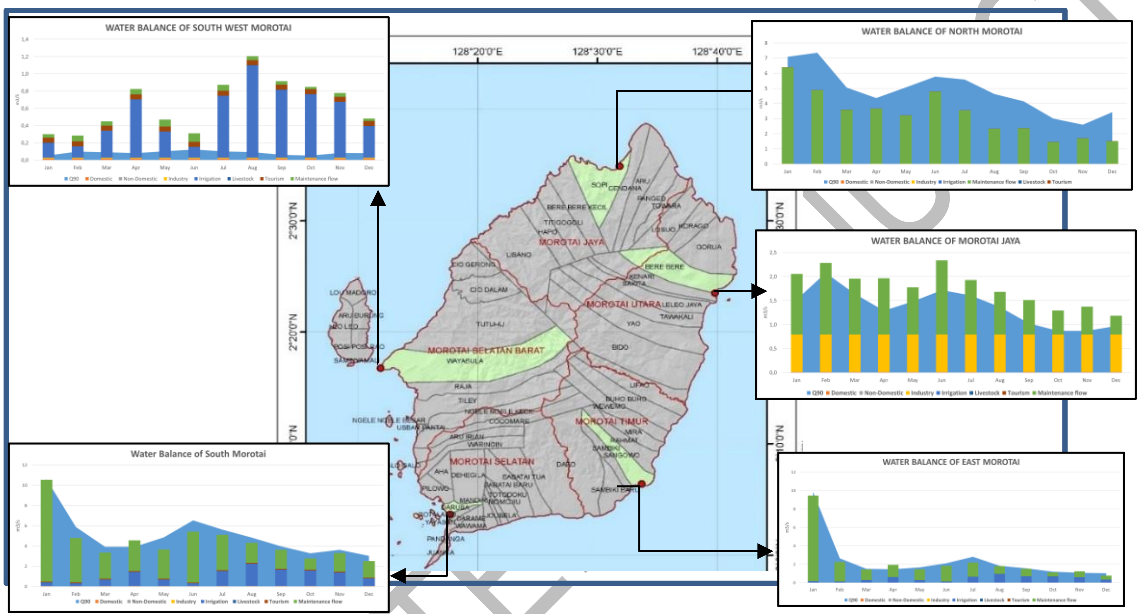

Figure 2 Water balance map in Morotai Island

3.4 Raw Water Supply Scheme

To overcome the water deficit that occurred in several regions and also to prepare for dealing with tourism development in Morotai Island, a raw water supply scheme has been prepared as follows:

1. Morotai Jaya has a good potential of the aquifer with average productivity in the coastal area of the North and East part, so that dug wells and drilled wells can be built to utilise groundwater. There is also potential spring, namely Ake Tatum spring and one catchment that has large enough recharge capacity namely Aru catchment, i.e. 339.6 mm/year.
2. North Morotai has potential surface water that can be developed by built free intake in Ngisio river, Kocago river, Sakita river, and Yao river; This region also has one potential recharge capacity in Lusuo catchment, i.e. 432.6 mm/year.
3. In the coastal area of South-West Morotai can be built dug wells and drilled wells since the aquifer has good potential to be utilised. Beside of that, the area of Tutuhu catchment also has big enough recharge capacity, i.e. 338.8 mm/year;
4. East Morotai has potential spring namely Wawemo spring, the potential aquifer in the coastal part, and also there are high enough recharge capacity in Sangowo and Sangowo Kecil catchment, i.e. 643.5 mm/year and 721.8 mm/year respectively;

5. South Morotai has productive aquifer in the coastal area, and there are potential springs that can be utilised namely Kaca spring and Cobubu Spring. There is one catchment that has large enough recharge capacity namely Sabatai Tua catchment, i.e. 697.5 mm/year
6. Raw water supply for small islands can utilise springs, dug wells with shallow depth so that the quality of groundwater is not affected by seawater intrusion, rivers by building free intake, rainwater harvesting, and so on.

4 CONCLUSION

This study concludes that Morotai Island can be well developed for various sectors, especially the tourism sector, since it is supported by the potential water resources, including river, spring, and groundwater. However, with the currently limited infrastructure, there is still a water deficit in some areas, especially during the dry season. It can be proven by the difficulty of the communities in accessing water, especially clean water with good quality. To overcome this problem, raw water supply scheme has been prepared, e.g. surface water utilization in North Morotai by constructing free intake; groundwater utilization in most area especially coastal area by constructing dug wells and drilled wells; spring water utilization in Morotai Jaya, East Morotai, and South Morotai by constructing spring water collection system. The water supply scheme suggests the appropriate infrastructure to support the raw water supply for local communities, as well as for the development of Morotai Island to be the new primary tourism destination in Indonesia. This study can be used as preliminary information for further research, especially related to the selection of appropriate infrastructure to utilise the available water resources. Furthermore, it can also be used as a reference for research related to the development of raw water supply in other small islands

DISCLAIMER

The authors declare no conflict of interest.

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